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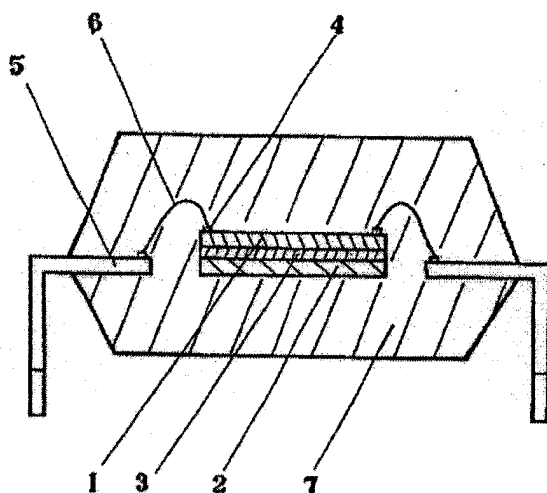
(54) [Title of the Invention] **Adhesive and Semiconductor Device**

(57) [Abstract]

[Object] To provide an adhesive that retains its wire bondability to a semiconductor pellet after said semiconductor pellet has been joined to a semiconductor pellet attachment member, and to provide a semiconductor device in which said semiconductor pellet and said semiconductor pellet attachment member are joined by the cured product of said adhesive, and which has excellent reliability.

[Constitution] An adhesive for joining a semiconductor pellet to a semiconductor pellet attachment member, composed of (A) an

organopolysiloxane having at least two silicon-bonded alkenyl groups per molecule, (B) an organopolysiloxane having at least two silicon-bonded hydrogen atoms per molecule, (C) an organosilicon compound having a silicon-bonded alkoxy group, (D) an organic or inorganic spherical filler whose particle diameter is 10 to 100 μm and whose major/minor axis ratio is 1.0 to 1.5, and (E) a catalytic amount of platinum or a platinum compound; and a semiconductor device characterized in that a semiconductor pellet and a semiconductor pellet attachment member are joined by the cured product of said adhesive.



[Claims]

[Claim 1] An adhesive for joining a semiconductor pellet to a semiconductor pellet attachment member, composed of:

(A) 100 weight parts organopolysiloxane having at least two silicon-bonded alkenyl groups per molecule;

(B) an organopolysiloxane having at least two silicon-bonded hydrogen atoms per molecule, in an amount such that there will be 0.5 to 3 mol of silicon-bonded hydrogen atoms in component B per mole of silicon-bonded alkenyl groups in component A;

(C) 0 to 10 weight parts organosilicon compound having a silicon-bonded alkoxy group;

(D) 0.1 to 100 weight parts organic or inorganic spherical filler whose particle diameter is 10 to 100 μm and whose major/minor axis ratio is 1.0 to 1.5; and

(E) a catalytic amount of platinum or a platinum compound.

[Claim 2] An adhesive as defined in Claim 1, characterized in that the standard deviation of the particle diameter distribution of component D is 3 μm or less.

[Claim 3] An adhesive as defined in Claim 1 or 2, characterized by containing no more than 500 ppm low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C in component A.

[Claim 4] A semiconductor device, characterized in that a semiconductor pellet and a semiconductor pellet attachment member are joined by a cured adhesive as defined in Claim 1, 2, or 3.

Detailed Description of the Invention

[0003]

Problems Which the Invention is Intended to Solve

However, when a semiconductor pellet and a semiconductor pellet [attachment member] are joined with the adhesive proposed in Japanese Laid-Open Patent Application H3-157474, and then, in the course of wire bonding to this semiconductor pellet, if the semiconductor pellet is vibrated or if the cured adhesive absorbs ultrasonic waves during ultrasonic hot press bonding, this can result in a marked decrease in the wire bondability to this semiconductor pellet, or the neck of the bonding wire may not have the proper shape, resulting in a marked decrease in the reliability of the resulting semiconductor device. This problem is more pronounced in a tiny semiconductor pellet, so the adhesive proposed in Japanese Laid-Open Patent Application H3-157474 was used with for larger semiconductor pellets, while an epoxy-based adhesive had to be used for tiny semiconductor pellets.

[0004] The inventors arrived at the present invention as a result of diligent research aimed at solving the above problems.

[0005] Specifically, it is an object of the present invention to provide an adhesive that retains its wire bondability to a semiconductor pellet after said semiconductor pellet has been joined to a semiconductor pellet attachment member, and to provide a semiconductor device in which said semiconductor pellet and said semiconductor pellet attachment member are joined by the cured product of said adhesive, and which has excellent reliability.

[0006]

Means Used to Solve the Above-Mentioned Problems and Operation of the Invention.

The present invention relates to an adhesive for joining a semiconductor pellet to a semiconductor pellet attachment member, composed of:

(A) 100 weight parts organopolysiloxane having at least two silicon-bonded alkenyl groups per molecule;

(B) an organopolysiloxane having at least two silicon-bonded hydrogen atoms per molecule, in an amount such that there will be 0.5 to 3 mol of silicon-bonded hydrogen atoms in component B per mole of silicon-bonded alkenyl groups in component A;

(C) 0 to 10 weight parts organosilicon compound having a silicon-bonded alkoxy group;

(D) 0.1 to 100 weight parts organic or inorganic spherical filler whose particle diameter is 10 to 100 μm and whose major/minor axis ratio is 1.0 to 1.5; and

(E) a catalytic amount of platinum or a platinum compound.

[0007] The present invention further relates to a semiconductor device, characterized in that a semiconductor pellet and a semiconductor pellet attachment member are joined by the cured product of the above-mentioned adhesive.

[0008] First, the adhesive of the present invention will be described in detail.

[0009] Component A is the main agent of this adhesive, and is an organopolysiloxane having at least two silicon-bonded alkenyl groups per molecule. Specific examples of the silicon-bonded alkenyl groups in component A include vinyl groups, allyl groups, butenyl groups, pentenyl groups, hexenyl groups, and heptenyl groups, with vinyl groups being preferred. There are no particular restrictions on the bonding positions of the alkenyl groups in component A, but examples include at the molecular chain terminals and/or molecular side chains. Specific examples of silicon-bonded organic groups other than alkenyl groups in component A include a methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, heptyl group, or other alkyl group; a phenyl group, tolyl group, xylyl group, naphthyl group, or other aryl group; a benzyl group, phenethyl group, or other aralkyl group; and a chloromethyl group, 3-chloropropyl group, 3,3,3-trifluoropropyl group, or other halogenated alkyl

group, with a methyl group or phenyl group being preferred. There are no particular restrictions on the molecular structure of component A, but examples include straight chain, branched, cyclic, reticulated, and partially branched straight chain, with straight chain being preferred.

[0010] Specific examples of the organopolysiloxane of component A include trimethylsiloxy-endblocked dimethylsiloxane-methylvinylsiloxane copolymers, trimethylsiloxy-endblocked methylvinylpolysiloxanes, trimethylsiloxy-endblocked dimethylsiloxane-methylvinylsiloxane-methylphenylsiloxane copolymers, dimethylvinylsiloxy-endblocked dimethylpolysiloxanes, dimethylvinylsiloxy-endblocked methylvinylpolysiloxanes, dimethylvinylsiloxy-endblocked dimethylsiloxane-methylvinylsiloxane copolymers, dimethylvinylsiloxy-endblocked dimethylsiloxane-methylvinylsiloxane-methylphenylsiloxane copolymers, organopolysiloxane copolymers composed of siloxane units expressed by the formula $R^1_3SiO_{1/2}$ and siloxane units expressed by the formula $SiO_{4/2}$, organopolysiloxane copolymers composed of siloxane units expressed by the formula $R^1_2R^2SiO_{1/2}$ and siloxane units expressed by the formula $SiO_{4/2}$, organopolysiloxane copolymers composed of siloxane units expressed by the formula $R^1R^2SiO_{2/2}$ and siloxane units expressed by the formula $R^1SiO_{3/2}$ or siloxane units expressed by the formula $R^2SiO_{3/2}$, and mixtures of two or more of these organopolysiloxanes. In the formulas, R^1 is a monovalent hydrocarbon group other than an alkenyl group, specific examples of which include a methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, heptyl group, or other alkyl group; a phenyl group, tolyl group, xylyl group, naphthyl group, or other aryl group; a benzyl group, phenethyl group, or other aralkyl group; and a chloromethyl group, 3-chloropropyl group, 3,3,3-trifluoropropyl group, or other halogenated alkyl group. R^2 in the formulas is an alkenyl group, specific examples of which include a vinyl group, allyl group, butenyl group, pentenyl group, hexenyl group, and heptenyl group.

[0011] The organopolysiloxane of component A can be manufactured by a known method, but the organopolysiloxane thus obtained contains approximately 2 to 7 wt% low molecular weight siloxane having an evaporation pressure of at least 10

mmHg at 200°C, such as octamethylcyclotetrasiloxane, decamethylcyclopentasiloxane, and dodecamethylcyclohexasiloxane. Consequently, if the semiconductor pellet and the semiconductor pellet attachment member are joined with an adhesive prepared using an organopolysiloxane containing approximately 2 to 7 wt% low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C as component A, then there is the danger of a decrease in the adhesion of an epoxy-based sealing resin to the semiconductor pellet. Accordingly, it is preferable for the amount in which the low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C is contained in component A to be reduced to no more than 500 ppm. Examples of methods for removing low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C from component A include a method in which the organopolysiloxane of component A is made into a thin film and heated to between 180 and 300°C under a reduced pressure of 0.5 mmHg, a method in which the organopolysiloxane of component A is washed with an organic solvent such as methanol, ethanol, propanol, butanol, or acetone, and a combination of these methods.

[0012] There are no particular restrictions on the viscosity of component A, but a range of 50 to 500,000 centipoise at 25°C is preferable, and a range of 400 to 100,000 centipoise is even better. This is because the mechanical strength of the resulting cured product will decrease if the viscosity of component A at 25°C is less than 50 centipoise, but the resulting adhesive will be more difficult to handle if the viscosity is over 500,000 centipoise.

[0013] Component B is the curing agent for this adhesive, and is an organopolysiloxane having at least two silicon-bonded hydrogen atoms per molecule. There are no particular restrictions on the bonding positions of the silicon-bonded hydrogen atoms in component B, but examples include at the molecular chain terminals and/or molecular side chains. Specific examples of silicon-bonded organic groups in component B include a methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, heptyl group, or

other alkyl group; a phenyl group, tolyl group, xylyl group, naphthyl group, or other aryl group; a benzyl group, phenethyl group, or other aralkyl group; and a chloromethyl group, 3-chloropropyl group, 3,3,3-trifluoropropyl group, or other halogenated alkyl group, with a methyl group or phenyl group being preferred. There are no particular restrictions on the molecular structure of component B, but examples include straight chain, branched, cyclic, reticulated, and partially branched straight chain, with straight chain being preferred.

[0014] Specific examples of the organopolysiloxane of component B include trimethylsiloxy-endblocked methylhydrogenpolysiloxanes, trimethylsiloxy-endblocked dimethylsiloxane-methylhydrogensiloxane copolymers, trimethylsiloxy-endblocked dimethylsiloxane-methylhydrogensiloxane-methylphenylsiloxane copolymers, dimethylhydrogensiloxy-endblocked dimethylpolysiloxanes, dimethylhydrogensiloxy-endblocked dimethylsiloxane-methylphenylsiloxane copolymers, dimethylhydrogensiloxy-endblocked methylphenylsiloxanes, organopolysiloxane copolymers composed of siloxane units expressed by the formula $R^1_3SiO_{1/2}$ and siloxane units expressed by the formula $R^1_2HSiO_{1/2}$ and siloxane units expressed by the formula $SiO_{4/2}$, organopolysiloxane copolymers composed of siloxane units expressed by the formula $R^1_2HSiO_{1/2}$ and siloxane units expressed by the formula $SiO_{4/2}$, organopolysiloxane copolymers composed of siloxane units expressed by the formula $R^1HSiO_{2/2}$ and siloxane units expressed by the formula $R^1SiO_{3/2}$ or siloxane units expressed by the formula $HSiO_{3/2}$, and mixtures of two or more of these organopolysiloxanes. In the formulas, R^1 is a monovalent hydrocarbon group other than an alkenyl group, specific examples of which include a methyl group, ethyl group, propyl group, butyl group, pentyl group, hexyl group, heptyl group, or other alkyl group; a phenyl group, tolyl group, xylyl group, naphthyl group, or other aryl group; a benzyl group, phenethyl group, or other aralkyl group; and a chloromethyl group, 3-chloropropyl group, 3,3,3-trifluoropropyl group, or other halogenated alkyl group.

[0015] The organopolysiloxane of component B can be manufactured by a known method, but the organopolysiloxane thus obtained contains a large amount of low

molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C, so just as with the above-mentioned component A, it is preferable for the amount in which the low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C is contained in component B to be low. Examples of methods for removing low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C from component B include a method in which the organopolysiloxane of component B is made into a thin film and heated to between 180 and 300°C under a reduced pressure of 0.5 mmHg, a method in which the organopolysiloxane of component B is washed with an organic solvent such as methanol, ethanol, propanol, butanol, or acetone, and a combination of these methods.

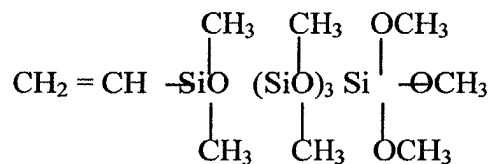
[0016] There are no particular restrictions on the viscosity of component B, but a range of 1 to 500,000 centipoise at 25°C is preferable, and a range of 5 to 100,000 centipoise is even better. This is because the mechanical strength of the resulting cured product will decrease if the viscosity of component B at 25°C is less than 1 centipoise, but the resulting adhesive will be more difficult to handle if the viscosity is over 500,000 centipoise.

[0017] Component B must be contained in an amount such that there are between 0.5 and 3 mol of the silicon-bonded hydrogen atoms in component B per mole of the silicon-bonded alkenyl groups in component A. This is because the resulting adhesive will not cure sufficiently if there is less than 0.5 mol of the silicon-bonded hydrogen atoms in component B per mole of the silicon-bonded alkenyl groups in component A, but the mechanical properties of the resulting cured product will change over time if this amount is over 3 mol.

[0018] Component C is a component that serves to increase the adhesion of the cured product obtained by curing this adhesive, and is an organosilicon compound having a silicon-bonded alkoxy group. Examples of the organosilicon compound of component C include tetramethoxysilane, tetraethoxysilane, dimethyldimethoxysilane, methylphenyldiethoxysilane, phenyltrimethoxysilane, methyltrimethoxysilane, methyltriethoxysilane, vinyltrimethoxysilane, allyltrimethoxysilane, allyltriethoxysilane, 3-glycidoxypropyltrimethoxysilane, 3-

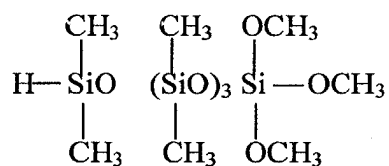
methacryloxypropyltrimethoxysilane, and other such alkoxy silane compounds, and compounds expressed by the formula:

[First Chemical Formula]



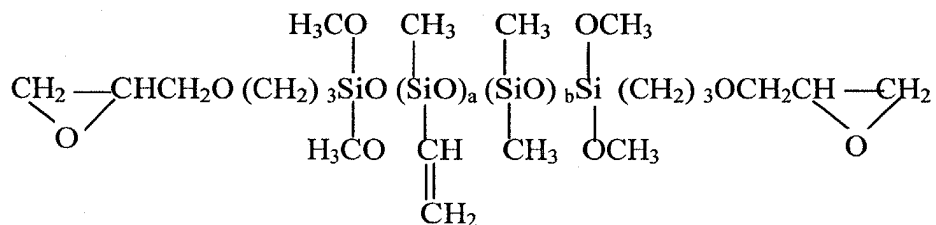
the formula:

[Second Chemical Formula]



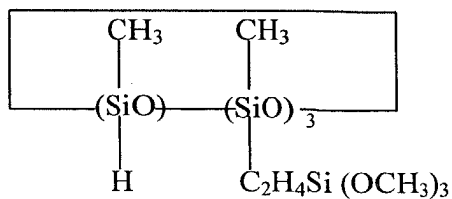
the formula:

[Third Chemical Formula]



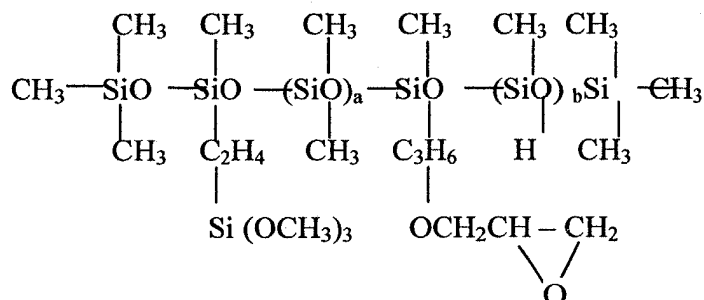
the formula:

[Fourth Chemical Formula]



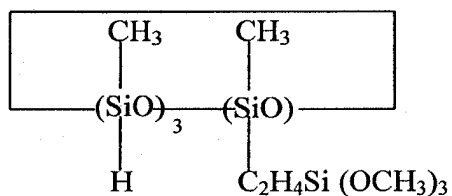
the formula:

[Fifth Chemical Formula]



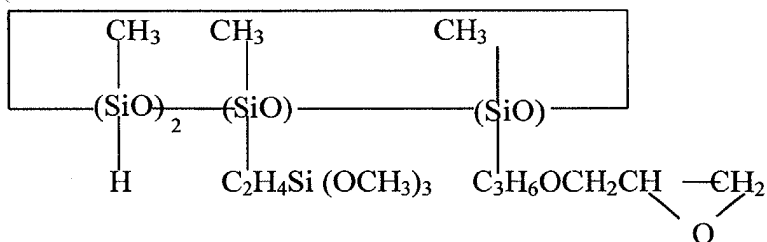
the formula:

[Sixth Chemical Formula]



or the formula:

[Seventh Chemical Formula]



(where a is an integer greater than or equal to 1, and b is an integer greater than or equal to 1). Of the organosilicon compounds of component C, one that has silicon-bonded alkoxy groups and silicon-bonded alkenyl groups or silicon-

bonded hydrogen atoms in its molecules is preferable as the organosilicon compound of component C because the resulting cured product will have particularly good adhesion.

[0019] Component C must be contained in an amount of 0 to 10 weight parts per 100 weight parts of component A, with a range of 0.5 to 3.0 weight parts being preferred. This is because the storage stability of the resulting adhesive will be poor if the component C content is more than 10 weight parts per 100 weight parts of component A.

[0020] Component D is the characteristic component of this adhesive, and is an organic or inorganic spherical filler that preserves wire bondability to a semiconductor pellet after the semiconductor pellet has been joined to a semiconductor pellet attachment member with the cured product of this adhesive. Specific examples of the organic or inorganic spherical filler of component D include polystyrene resin, acrylic resin, polycarbonate resin, nylon resin, polydivinylbenzene resin, and other such organic spherical fillers, and gold, silver, copper, tin, nickel, and other metals, silica, titanium oxide, and other metal oxides, glass, and other such inorganic spherical fillers. The particle diameter of component D must be between 10 and 100 μm , and preferably between 10 and 40 μm , and the major/minor axis ratio must be between 1.0 and 1.5. This is because if the particle diameter of component D is less than 10 μm or over 100 μm , there will be a pronounced loss of wire bondability to the semiconductor pellet after the semiconductor pellet and the semiconductor pellet attachment member have been joined by the adhesive, and there will similarly be a pronounced loss of wire bondability to the semiconductor pellet if the major/minor axis ratio is over 1.5. The organic or inorganic spherical filler of component D must be in the form of spheres with a uniform size, and it is preferable for the particle diameter distribution thereof to have a standard deviation of no more than 3.0 μm . There are no particular restrictions on the method for preparing this organic or inorganic spherical filler of component D, but it is preferable for the particles to be graded so that their diameter is between 10 and 100 μm and their major/minor axis ratio is between 1.0 and 1.5.

[0021] The amount in which component D is contained must be between 0.1 and 100 weight parts per 100 weight parts of component A, with a range of 0.5 to 20 weight parts being preferred. This is because if component D is contained in an amount less than 0.1 weight part per 100 weight parts of component A, there will be a pronounced loss of wire bondability to the semiconductor pellet after the semiconductor pellet and the semiconductor pellet attachment member have been joined by the adhesive, but if this amount is over 100 weight parts, the viscosity of the resulting adhesive will be so high that the handling thereof will be much more difficult.

[0022] Component E is platinum or a platinum compound, which serves to promote the curing of this adhesive. Specific examples of the platinum or platinum compound of component E include platinum fines, platinum black, platinum supported on alumina powder, platinum supported on activated charcoal, chloroplatinic acid, platinum tetrachloride, alcohol solutions of chloroplatinic acid, platinum-olefin complexes, platinum-divinyltetramethyldisiloxane complexes, and thermoplastic resin powders such as polystyrene resin, nylon resin, polycarbonate resin, and silicone resin with a particle size of less than 10 μm and containing platinum or a platinum compound.

[0023] Component E is contained in a catalytic amount. For example, it is preferable for the platinum metal to be contained in component E in this adhesive in an amount of 0.1 to 500 ppm (by weight), with a range of 1 to 50 ppm being even better. This is because there will be pronounced decrease in the curing rate of the resulting adhesive if the platinum metal is contained in component E of this adhesive is an amount less than 0.1 weight part (by weight), and exceeding 500 weight parts is unfavorable from a cost standpoint.

[0024] The adhesive of the present invention can be prepared by uniformly mixing the above-mentioned components A to E. To the extent that the object of the present invention is not compromised, the adhesive of the present invention may also contain other components as needed, such as a curing inhibitor for making the adhesive of the present invention easier to handle and improving its storage stability. Specific examples of such curing inhibitors include 3-methyl-1-

butyn-3-ol, 3,5-dimethyl-1-hexyn-3-ol, phenylbutynol, and other such alkyne alcohols; 3-methyl-3-penten-1-yne, 3,5-dimethyl-3-hexen-1-yne, and other such ene-yne compounds; and 1,3,5,7-tetramethyl-1,3,5,7-tetravinylcyclotetrasiloxane, 1,3,5,7-tetramethyl-1,3,5,7-tetrahexenylcyclotetrasiloxane, and benzotriazole. This curing inhibitor is preferably contained in the adhesive of the present invention in an amount of 10 to 50,000 ppm (by weight).

[0025] Also, to the extent that the object of the present invention is not compromised, the adhesive of the present invention can contain an inorganic filler with a particle size of less than 10 μm in order to impart suitable hardness and strength to the resulting cured product, and to make the adhesive of the present invention easier to handle. Specific examples of such inorganic fillers include fumed silica, precipitated silica, titanium dioxide, carbon black, alumina, powdered quartz, or one of these inorganic fillers that has undergone a surface treatment with an organosilicon compound such as an organoalkoxysilane, organochlorosilane, or organosilazane. It is preferable if the adhesive of the present invention contains this inorganic filler in an amount less than 100 weight parts, and even more preferably 0.1 to 20 weight parts, per 100 weight parts of component A.

[0026] The adhesive of the present invention is particularly favorable as an adhesive for tiny semiconductor pellets because wire bondability to the semiconductor pellets is not lost after semiconductor pellets are joined to a semiconductor pellet attachment member. In a semiconductor device in which semiconductor pellets of different sizes are mounted on a circuit substrate, both large semiconductor pellets and tiny semiconductor pellets can be joined to the semiconductor pellet attachment member with the adhesive of the present invention, which simplifies the semiconductor device manufacturing process. Examples of methods for joining a semiconductor pellet and a semiconductor pellet attachment member with the adhesive of the present invention include a method in which the semiconductor pellet attachment member is coated with this adhesive and the semiconductor pellet is then pressed against the adhesive and heated, and a method in which the semiconductor pellet is coated with the

adhesive and then pressed against the semiconductor pellet attachment member and heated. There are no particular restrictions on the temperature at which the adhesive of the present invention is cured, but a temperature of 50 to 200°C is good, for example, with 100 to 150°C being even better.

[0027] The semiconductor device of the present invention will now be described in detail through reference to the drawings.

[0028] As shown in Fig. 1, the semiconductor device of the present invention is characterized in that a semiconductor pellet 1 and a semiconductor pellet attachment member 2 are joined with the cured product 3 of the above-mentioned adhesive. With the semiconductor device of the present invention, the semiconductor pellet 1 comprises an electronic circuit formed on the surface of silicon, gallium-arsenic, or the like, and the semiconductor pellet attachment member 2 is composed of a metal such as copper or an iron alloy, and is usually referred to as a tab. As shown in Fig. 2, the semiconductor device of the present invention is characterized in that a circuit substrate 8 is used as the semiconductor pellet attachment member, and the semiconductor pellet 1 and the circuit substrate 8 are joined by the cured product 3 of the above-mentioned adhesive. With the semiconductor device of the present invention, the circuit substrate 8 is composed of a substrate of ceramic, glass, or the like, on the surface of which is formed circuit wiring 9 made of metal such as gold, silver, or copper. A capacitor, resistor, coil, or other such electrical element may also be mounted on the surface of the circuit substrate 8.

[0029] The semiconductor device of the present invention is produced by bringing the semiconductor pellet 1 against the semiconductor pellet attachment member 2 or the circuit substrate 8 with the above-mentioned adhesive, then heating this to form the cured product 3 of this adhesive, and then wire-bonding with bonding wire 6 made of gold, copper, aluminum, or another metal the circuit wiring 9 or a lead frame 5 and a bonding pad 4 provided at the upper end of the semiconductor pellet. Ultrasonic press bonding, hot press bonding, ultrasonic hot press bonding, or another such method is generally used for the wire bonding with the bonding wire 6. Examples of methods for joining the semiconductor

pellet 1 to the semiconductor pellet attachment member 2 or the circuit substrate 8 with the cured product 3 of the above-mentioned adhesive include a method in which the semiconductor pellet attachment member 2 or the circuit substrate 8 is coated with this adhesive and the semiconductor pellet 1 is then pressed against the adhesive and heated, and a method in which the semiconductor pellet 1 is coated with the adhesive and then pressed against the semiconductor pellet attachment member 2 or the circuit substrate 8 via the adhesive and heated. There are no particular restrictions on the temperature at which the above-mentioned adhesive is cured, but a temperature of 50 to 200°C is good, for example, with 100 to 150°C being even better.

[0030] It is preferable with the semiconductor device of the present invention if the surface of the semiconductor pellet 1 is coated with a gel- or rubber-form silicone coating agent after wire bonding to this semiconductor pellet 1. It is also preferable for this semiconductor pellet 1 to be sealed with an epoxy-based sealing resin 6.¹

[0031]

Examples

The adhesive and semiconductor device of the present invention will now be described in detail through examples. The viscosity in these examples was measured at 25°C. The low molecular weight siloxane content was measured and the characteristics of the adhesive and semiconductor device were evaluated in the examples by the following methods.

[0032] Measurement of low molecular weight siloxane content: The low molecular weight siloxane contained in the adhesive or an organopolysiloxane was extracted with acetone, after which the amount of low molecular weight siloxane extracted with acetone was quantified by gas chromatography (GC-9A made by Shimadzu Seisakusho, FID specifications). The amount of low molecular weight siloxane having an evaporation pressure of at least 10 mmHg

¹ Translator's note: "6" was used above for the bonding wire; probable error for "7."

at 200°C contained in the adhesive or organopolysiloxane was determined from the above amount of low molecular weight siloxane.

[0033] Hardness of cured product obtained by curing of adhesive: The hardness of the cured product obtained by heating the adhesive for 10 minutes at 150°C was measured with the JIS A hardness tester discussed in JIS K 6301.

[0034] Production of semiconductor device and evaluation of wire bondability: After the semiconductor pellet 1 and the semiconductor pellet attachment member 2 were held together with the adhesive, they were heated for 1 minute at 200°C to form the cured product 3 of the adhesive. After this, the bonding pad 4 and the lead frame 5 provided to the top end of the semiconductor pellet 1 were wire bonded with the bonding wire 6. This wire bonding with the bonding wire 6 was performed by ultrasonic hot press bonding at a joining temperature of 160 to 250°C and a load of 30 100 mg/wire. The neck shape between the bonding wire 6 and the bonding pad 4 and between the bonding wire 6 and the lead frame 5 was then examined under a microscope. The joining state of this bonding wire 6 was examined by pulling on the bonding wire 6, and wire bondability was evaluated from the proportion of defective joints of the bonding wires 6 versus the total number of wires.

[0035] Semiconductor device malfunction rate

The semiconductor device was plugged into a socket, and a conductivity test was conducted between the terminals of the lead frame 5. In this conductivity test, the proportion of conductivity failures in the semiconductor device was evaluated as the malfunction rate of the semiconductor device.

[0036] Reference Example 1

1,1,3,3,5,5,7,7-octamethylcyclotetrasiloxane and 1,3-divinyl-1,1,3,3-tetramethyldisiloxane were subjected to equilibrium polymerization using potassium silanolate, after which this product was neutralized with trimethylcyclasilane to prepare a dimethylvinylsiloxy-endblocked dimethylpolysiloxane (I). The amount of low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C contained in this

dimethylpolysiloxane (I) was 20.5 wt%. This dimethylpolysiloxane (I) was heated for 5 hours at 180°C under a reduced pressure of 10 mmHg to prepare a dimethylvinylsiloxy-endblocked dimethylpolysiloxane (II) (vinyl group content: 0.23 wt%) with a viscosity of 2000 centipoise and containing 1.3 wt% low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C. This dimethylpolysiloxane (II) was then subjected to a heat treatment for 8 hours at 260°C and a reduced pressure of 0.01 mmHg in a molecular distillation apparatus to prepare a dimethylvinylsiloxy-endblocked dimethylpolysiloxane (III) (vinyl group content: 0.23 wt%) with a viscosity of 2000 centipoise and containing 0.01 wt% low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C. 100 weight parts of this dimethylpolysiloxane (III) and 300 parts ethanol were stirred for 3 hours and then allowed to stand to separate the ethanol. This procedure was repeated 4 times, after which the ethanol dissolved in this dimethylpolysiloxane was heated for 5 hours at 180°C under a reduced pressure of 10 mmHg to prepare a dimethylvinylsiloxy-endblocked dimethylpolysiloxane (IV) (vinyl group content: 0.23 wt%) with a viscosity of 2000 centipoise and containing 10 ppm low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C.

[0037] Reference Example 2

65 weight parts of the dimethylvinylsiloxy-endblocked dimethylpolysiloxane (III) prepared in Reference Example 1 was mixed with 35 weight parts of an organopolysiloxane copolymer (vinyl group content: 1.85 wt%) composed of $(\text{CH}_3)_3\text{SiO}_{1/2}$ units, $(\text{CH}_3)_2(\text{CH}_2=\text{CH})\text{SiO}_{1/2}$ units, and $\text{SiO}_{4/2}$ units to prepare an organopolysiloxane mixture (vinyl group content: 0.80 wt%) with a viscosity of 9000 centipoise. 100 weight parts of this organopolysiloxane mixture and 300 weight parts ethanol were stirred for 3 hours and then allowed to stand to separate the ethanol. This procedure was repeated 4 times, after which the ethanol dissolved in this siloxane mixture was heated for 5 hours at 180°C under a reduced pressure of 10 mmHg to prepare an organopolysiloxane mixture (V)

(vinyl group content: 0.80 wt%) with a viscosity of 9000 centipoise. The amount of low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C contained in this organopolysiloxane mixture (V) was 10 ppm.

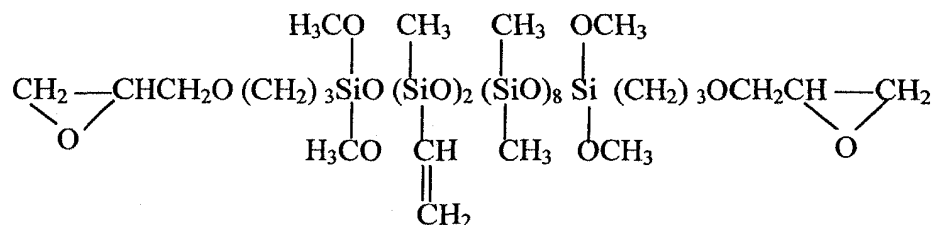
[0038] Reference Example 3

1,1,3,3,5,5,7,7-octamethylcyclotetrasiloxane, 1,1,3,3-tetramethyldisiloxane, and 1,3,5,7-tetramethylcyclotetrasiloxane were subjected to equilibrium polymerization using activated clay, after which this product was filtered to prepare a dimethylhydrogensiloxy-endblocked dimethylsiloxane-methylhydrogensiloxane copolymer (VI) (silicon-bonded hydrogen atom content: 0.6 wt%) with a viscosity of 10 centipoise. The amount of low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C contained in this dimethylsiloxane-methylhydrogensiloxane copolymer (VI) was 17.0 wt%. This dimethylsiloxane-methylhydrogensiloxane copolymer (VI) was heated for 3 hours at 180°C under a reduced pressure of 5 mmHg to prepare a dimethylhydrogensiloxy-endblocked dimethylsiloxane-methylhydrogensiloxane copolymer (VII) (silicon-bonded hydrogen atom content: 0.6 wt%) with a viscosity of 10 centipoise and containing 100 ppm low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C.

[0039] Example 1

100 weight parts of the dimethylvinylsiloxy-endblocked dimethylpolysiloxane (II), 2.6 weight parts of a trimethylsiloxy-endblocked methylhydrogenpolysiloxane (silicon-bonded hydrogen atom content: 1.57 wt%) with a viscosity of 30 centipoise, 16 weight parts of glass beads with a diameter of 30 μm (standard deviation of bead diameter distribution: 1.1 μm) and a major/minor axis ratio of 1.04, 10 weight parts of hydrophobic fumed silica with a specific surface area of 200 m^2/g that had been surface treated with hexamethyldisilazane, 1.3 weight parts of an organosilicon compound expressed by the formula:

[Eighth Chemical Formula]



a complex of platinum and divinyltetramethyldisiloxane (in an amount such that the present composition would contain 5 ppm (by weight) platinum metal in the complex), and phenylbutynol (in an amount of 200 ppm (by weight) in the present composition) were uniformly mixed to prepare the adhesive of the present invention. This adhesive was cured for 10 minutes at 150°C, after which the hardness of the cured product was measured with the JIS A hardness tester discussed in JIS K 6301. A semiconductor device was then produced using this adhesive, and the wire bondability and moisture resistance of this semiconductor device were measured. These results are given in Table 1.

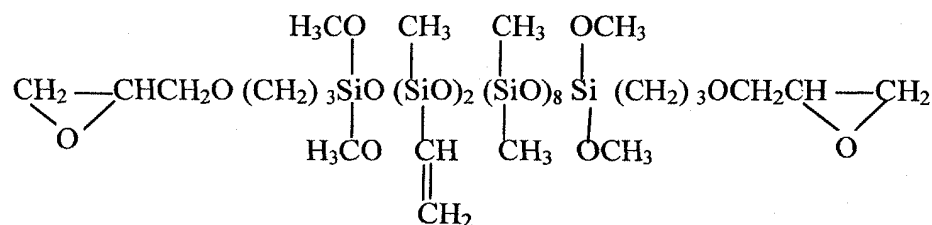
[0040] Comparative Example 1

Other than not adding the glass beads used in Example 1, which had a diameter of 30 μm (standard deviation of bead diameter distribution: 1.1 μm) and a major/minor axis ratio of 1.04, a comparative adhesive was prepared in the same manner as in Example 1. This adhesive was cured for 10 minutes at 150°C, after which the hardness of the cured product was measured with the JIS A hardness tester discussed in JIS K 6301. A semiconductor device was then produced using this adhesive, and the wire bondability and moisture resistance of this semiconductor device were measured. These results are given in Table 1.

[0041] Example 2

100 weight parts of the dimethylvinylsiloxyl-endblocked dimethylpolysiloxane (IV), 1.7 weight parts of the dimethylhydrogensiloxyl-endblocked dimethylsiloxane-methylhydrogensiloxane copolymer (VII), 1.1 weight parts of polystyrene beads with a diameter of 20 μm (standard deviation of bead diameter distribution: 1.2 μm) and a major/minor axis ratio of 1.06, 9 weight parts of hydrophobic fumed silica with a specific surface area of 200 m^2/g that had been surface treated with hexamethyldisilazane, 0.6 weight part of an organosilicon compound expressed by the formula:

[Ninth Chemical Formula]



a complex of platinum and 1,3-divinyl-1,1,3,3-tetramethyldisiloxane (in an amount such that the present composition would contain 5 ppm (by weight) platinum metal in the complex), and phenylbutynol (in an amount of 200 ppm (by weight) in the present composition) were uniformly mixed to prepare the adhesive of the present invention. The amount of low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C contained in this adhesive was 10 ppm. A gas chromatograph was used to measure the volatile component that resulted when the adhesive was cured by being heated for 10 minutes at 200°C, which revealed the amount of this component to be 100 ppm. Also, this adhesive was cured for 10 minutes at 150°C, after which the hardness of the cured product was measured with the JIS A hardness tester discussed in JIS K 6301. A semiconductor device was then produced using this adhesive, and the wire bondability and moisture resistance of this semiconductor device were measured. These results are given in Table 1.

[0042] Comparative Example 2

Other than using 15 weight parts of amorphous silica fines with a particle diameter of 40 μm and a particle diameter distribution of 3 to 100 μm instead of the polystyrene beads used in Example 2, which had a diameter of 20 μm (standard deviation of bead diameter distribution: 1.2 μm) and a major/minor axis ratio of 1.06, a comparative adhesive was prepared in the same manner as in Example 2. The amount of low molecular weight siloxane having an evaporation pressure of at least 15 mmHg at 200°C contained in this adhesive was 10 ppm. A gas chromatograph was used to measure the volatile component that resulted when the adhesive was cured by being heated for 10 minutes at 200°C, which revealed the amount of this component to be 100 ppm. Also, this adhesive was cured for 10 minutes at 150°C, after which the hardness of the cured product was measured with the JIS A hardness tester discussed in JIS K 6301. A semiconductor device was then produced using this adhesive, and the wire bondability and moisture resistance of this semiconductor device were measured. These results are given in Table 1.

[0043] Example 3

100 weight parts of the silicone mixture (V), 3.5 weight parts of the dimethylhydrogensiloxy-endblocked dimethylsiloxane-methylhydrogensiloxane copolymer (VII), 8 weight parts of spherical, synthetic silica beads with a diameter of 35 μm (standard deviation of bead diameter distribution: 2.5 μm) and a major/minor axis ratio of 1.2, 2.5 weight parts of 3-glycidoxypropyltrimethoxysilane, a complex of platinum and 1,3-divinyl-1,1,3,3-tetramethyldisiloxane (in an amount such that the present composition would contain 5 ppm (by weight) platinum metal in the complex), and phenylbutynol (in an amount of 150 ppm (by weight) in the present composition) were uniformly mixed to prepare the adhesive of the present invention. The amount of low molecular weight siloxane having an evaporation pressure of at least 10 mmHg at 200°C contained in this adhesive was 15 ppm. A gas chromatograph was

used to measure the volatile component that resulted when then adhesive was cured by being heated for 10 minutes at 200°C, which revealed the amount of this component to be 120 ppm. Also, this adhesive was cured for 10 minutes at 150°C, after which the hardness of the cured product was measured with the JIS A hardness tester discussed in JIS K 6301. A semiconductor device was then produced using this adhesive, and the wire bondability and moisture resistance of this semiconductor device were measured. These results are given in Table 1.

[0044] Comparative Example 3

Other than using 100 weight parts of a silver powder with a particle diameter of 10 μm (standard deviation of particle diameter distribution: 5 μm) and a major/minor axis ratio of 2.0 instead of the spherical, synthetic silica beads used in Example 3, which had a diameter of 35 μm (standard deviation of bead diameter distribution: 2.5 μm) and a major/minor axis ratio of 1.2, a comparative adhesive was prepared in the same manner as in Example 3. The amount of low molecular weight siloxane having an evaporation pressure of at least 15 mmHg at 200°C contained in this adhesive was 15 ppm. A gas chromatograph was used to measure the volatile component that resulted when then adhesive was cured by being heated for 10 minutes at 200°C, which revealed the amount of this component to be 120 ppm. Also, this adhesive was cured for 10 minutes at 150°C, after which the hardness of the cured product was measured with the JIS A hardness tester discussed in JIS K 6301. A semiconductor device was then produced using this adhesive, and the wire bondability and moisture resistance of this semiconductor device were measured. These results are given in Table 1.

[0045]

Table 1

	Present invention				Comparative Example		
	Example 1		Ex. 2	Ex. 3	1	2	3
Hardness of cured adhesive (JIS A)	30	30	28	35	30	30	50
Number of lead frames (number of pins)	12	64	7	12	12	7	12
Size of semiconductor pellet (mm × mm)	1.5 × 1.5	10.0 × 12.5	3.0 × 2.5	2.0 × 2.5	1.5 × 1.5	3.0 × 2.5	2.0 × 2.5
Number of tests of semiconductor device	50	30	50	50	50	50	50
Wire bondability	0/600	0/1920	0/350	0/600	138/600	56/350	120/600
Malfunction rate of semiconductor device	0/50	0/30	0/50	0/50	50/50	50/50	50/50

[0046]

Effect of the Invention

Because the adhesive of the present invention is composed of components A to E, and particularly because it contains an organic or inorganic spherical filler as component D, it is characterized in that there is no loss of wire bondability to a semiconductor pellet after said semiconductor pellet has been joined to a semiconductor pellet attachment member, and because the semiconductor device of the present invention is such that a semiconductor pellet and a semiconductor pellet attachment member are joined with the cured product of said adhesive, it is characterized by excellent reliability.

Brief Description of the Drawings

Fig. 1 is a cross section of the semiconductor device in an example of the semiconductor device of the present invention used in the examples; and

Fig. 2 is also a cross section of the semiconductor device in an example of the semiconductor device of the present invention.

Key:

- 1 silicon-based semiconductor pellet
- 2 copper semiconductor pellet attachment member
- 3 cured adhesive
- 4 aluminum bonding pad
- 5 copper lead frame
- 6 gold bonding wire
- 7 epoxy-based sealing resin
- 8 ceramic circuit substrate
- 9 copper circuit wiring
- 10 capacitor, resistor, or other electrical element

Figure 1

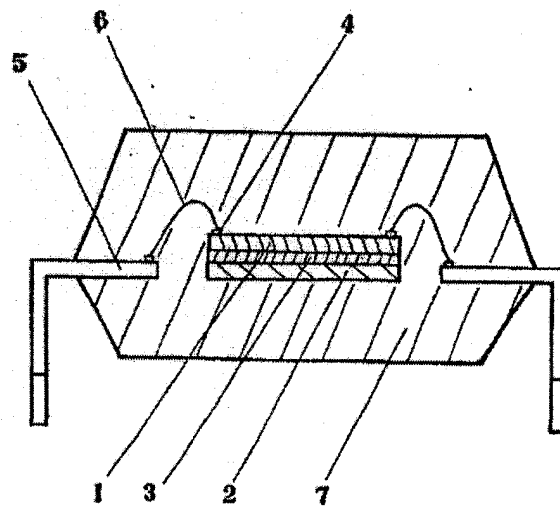


Figure 2

